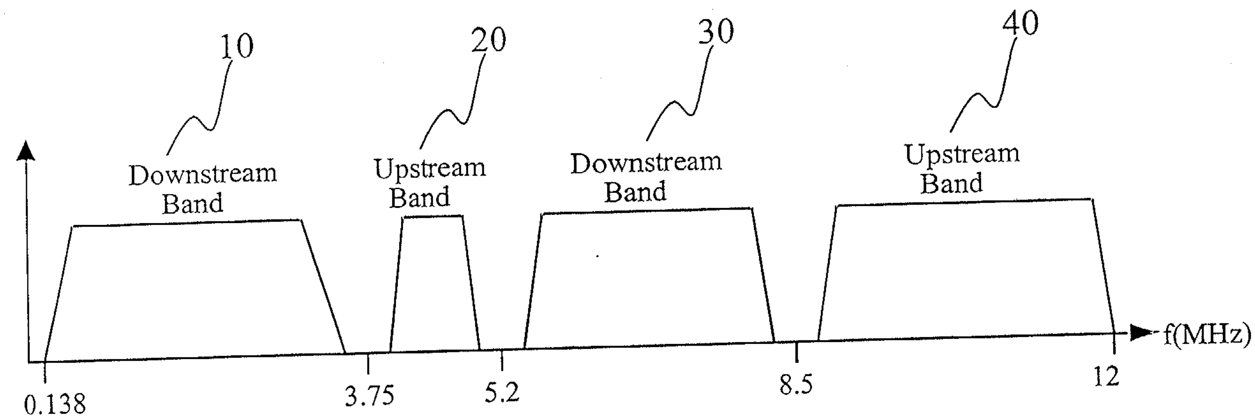


FIG. 1: Example VDSL Spectral Plan

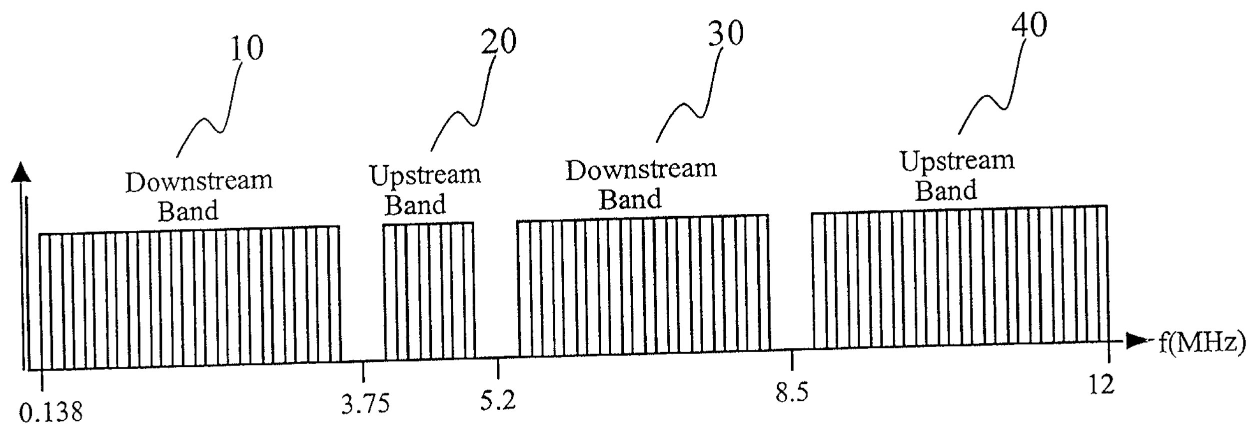


FIG. 2: Multi-Carrier Modulation Implementation of Example VDSL Spectral Plan

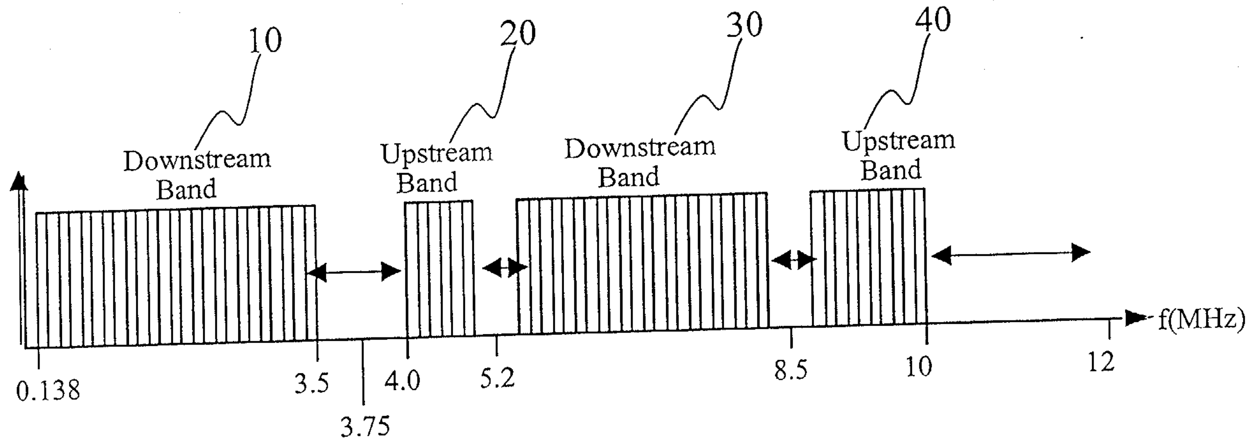


FIG. 3: Adjustment of Total Bandwidth in an MCM System

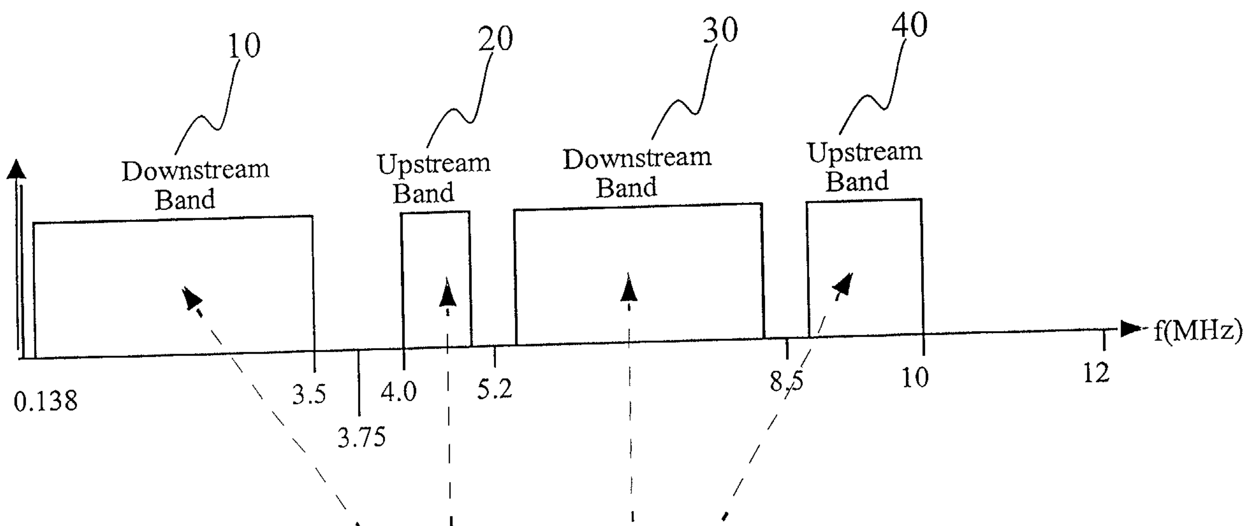
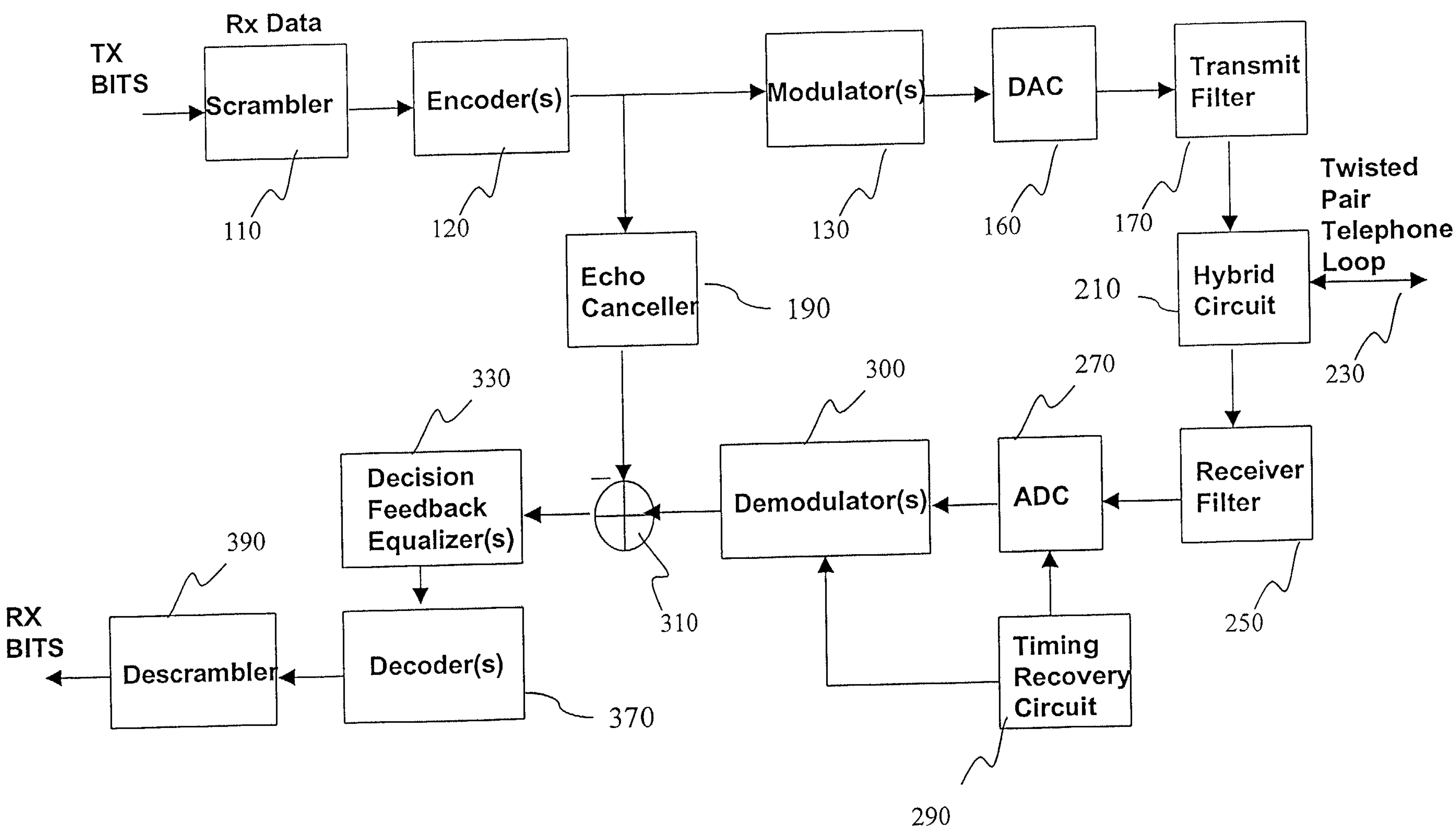


FIG. 4: Adjustment of Total Bandwidth in a SCM System



Rx Data
TX BITS
Scrambler
110
Encoder(s)
120
Modulator(s)
130
DAC
160
Transmit Filter
170
Twisted Pair Telephone Loop
Hybrid Circuit
210
230
Echo Canceller
190
330
300
270
Decision Feedback Equalizer(s)
Demodulator(s)
ADC
Receiver Filter
390
310
250
RX BITS
Descrambler
Decoder(s)
370
Timing Recovery Circuit
290

FIG. 5

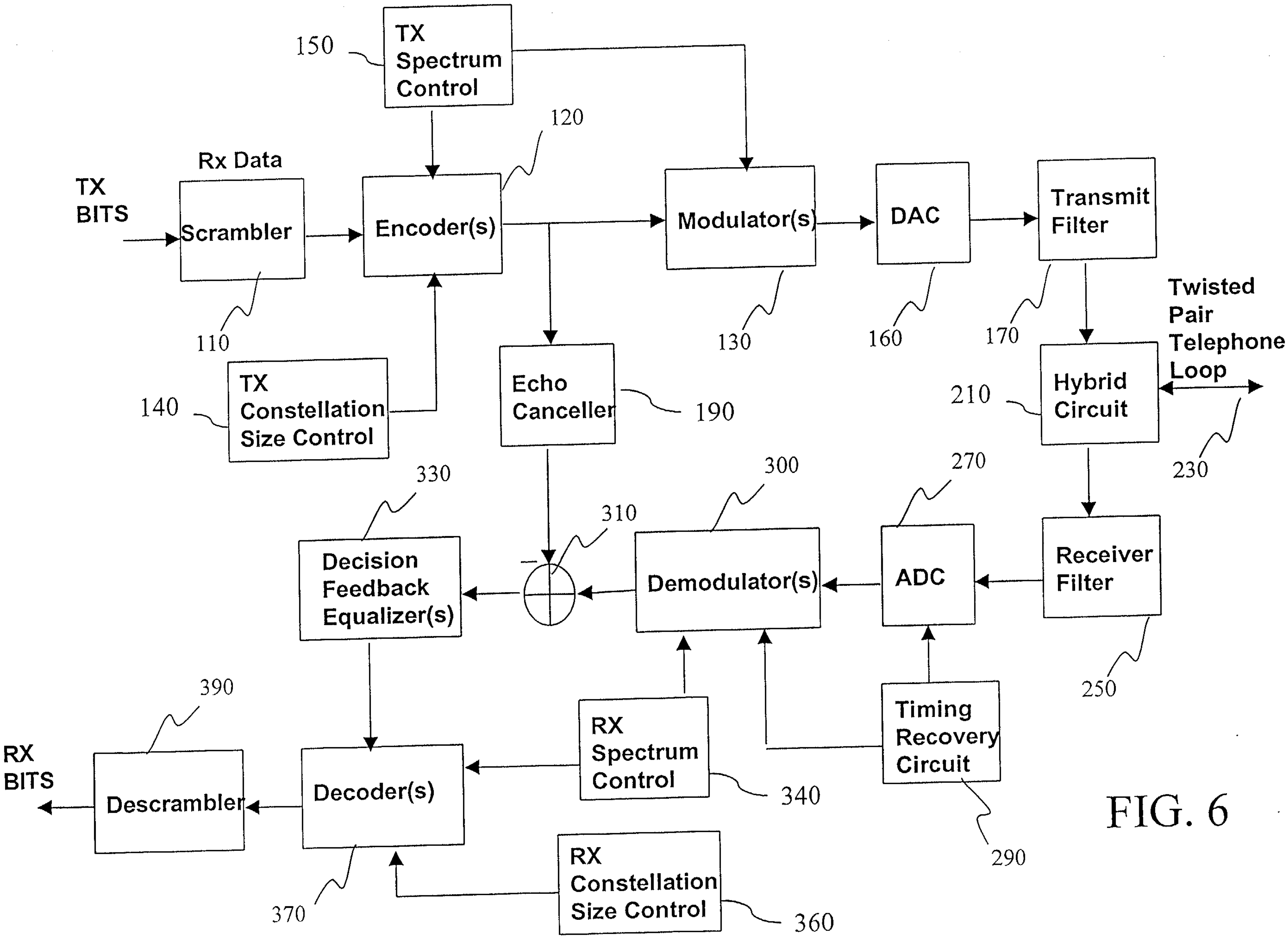

TX BITS
Rx Data
Scrambler
110
150
TX Spectrum Control
Encoder(s)
120
140
TX Constellation Size Control
Echo Canceller
190
Modulator(s)
130
DAC
160
Transmit Filter
170
Twisted Pair Telephone Loop
Hybrid Circuit
210
230
Receiver Filter
250
ADC
270
Demodulator(s)
300
310
Decision Feedback Equalizer(s)
330
Timing Recovery Circuit
290
RX Spectrum Control
340
Decoder(s)
370
RX Constellation Size Control
360
Descrambler
390
RX BITS

FIG. 6

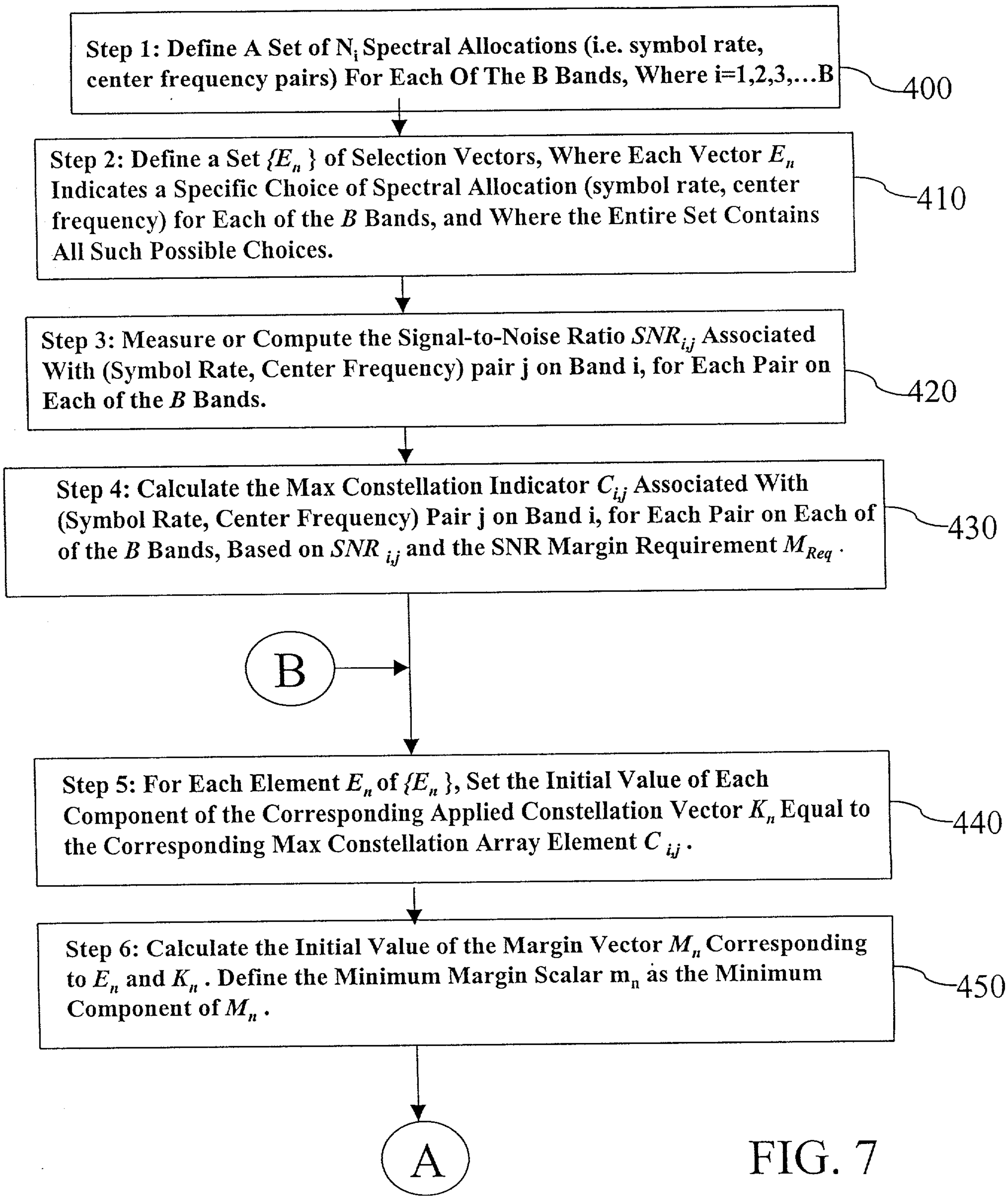

Step 1: Define A Set of N_i Spectral Allocations (i.e. symbol rate, center frequency pairs) For Each Of The B Bands, Where i=1,2,3,…B
400
Step 2: Define a Set $\{E_n\}$ of Selection Vectors, Where Each Vector E_n Indicates a Specific Choice of Spectral Allocation (symbol rate, center frequency) for Each of the B Bands, and Where the Entire Set Contains All Such Possible Choices.
410
Step 3: Measure or Compute the Signal-to-Noise Ratio $SNR_{i,j}$ Associated With (Symbol Rate, Center Frequency) pair j on Band i, for Each Pair on Each of the B Bands.
420
Step 4: Calculate the Max Constellation Indicator $C_{i,j}$ Associated With (Symbol Rate, Center Frequency) Pair j on Band i, for Each Pair on Each of of the B Bands, Based on $SNR_{i,j}$ and the SNR Margin Requirement M_{Req}.
430
B
Step 5: For Each Element E_n of $\{E_n\}$, Set the Initial Value of Each Component of the Corresponding Applied Constellation Vector K_n Equal to the Corresponding Max Constellation Array Element $C_{i,j}$.
440
Step 6: Calculate the Initial Value of the Margin Vector M_n Corresponding to E_n and K_n. Define the Minimum Margin Scalar m_n as the Minimum Component of M_n.
450
A

FIG. 7

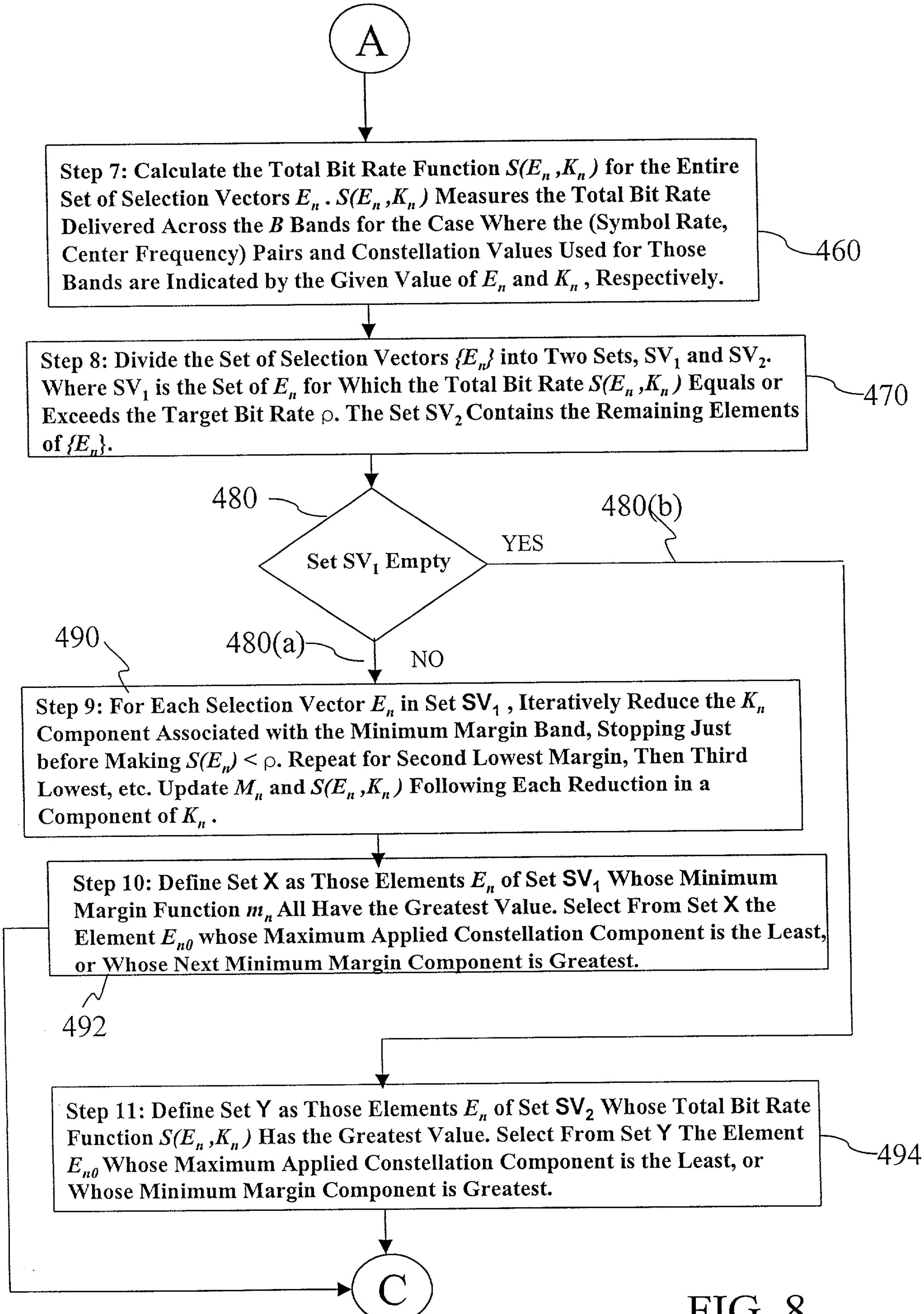
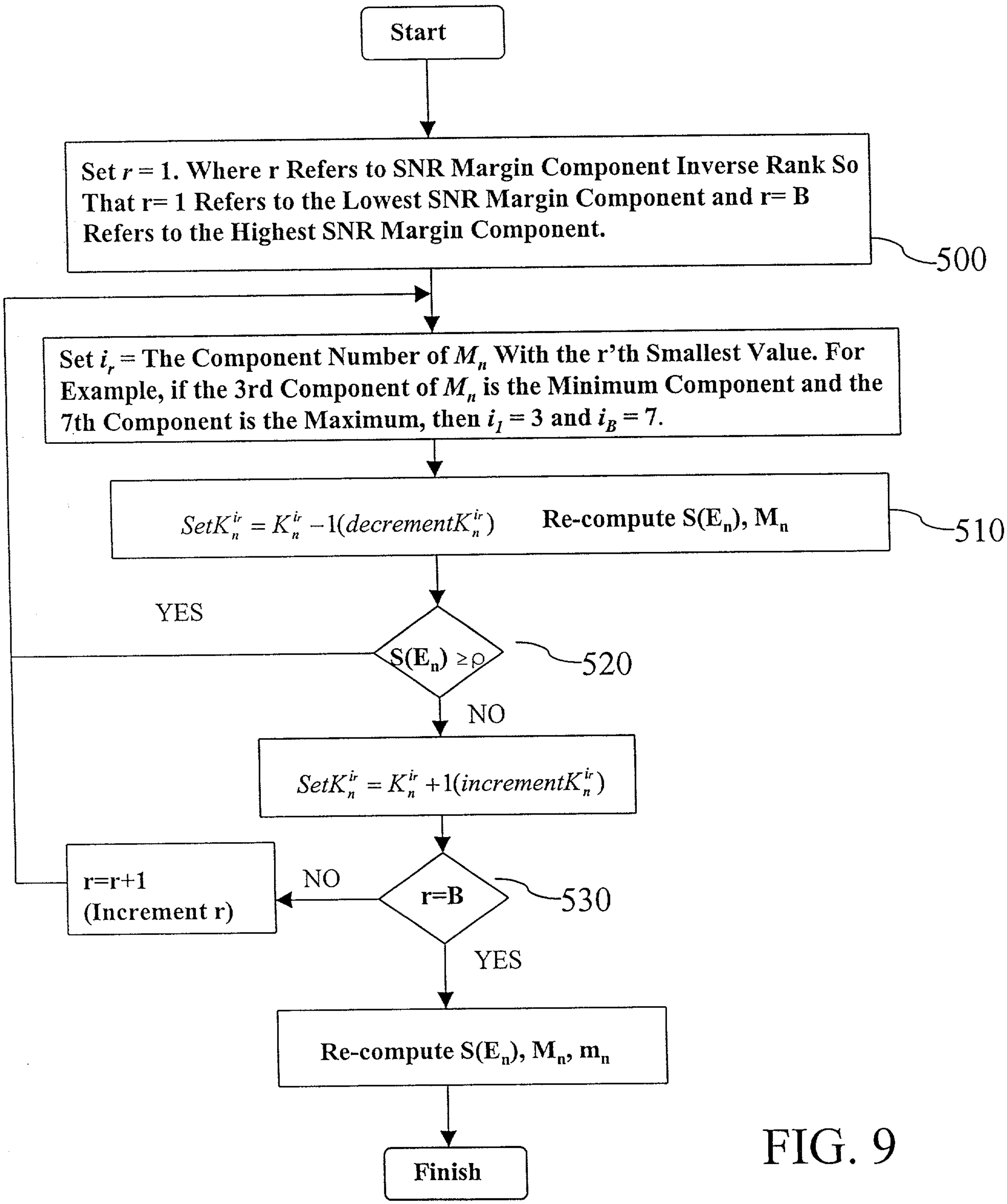

A
Step 7: Calculate the Total Bit Rate Function $S(E_n, K_n)$ for the Entire Set of Selection Vectors E_n. $S(E_n, K_n)$ Measures the Total Bit Rate Delivered Across the B Bands for the Case Where the (Symbol Rate, Center Frequency) Pairs and Constellation Values Used for Those Bands are Indicated by the Given Value of E_n and K_n, Respectively.
460
Step 8: Divide the Set of Selection Vectors $\{E_n\}$ into Two Sets, SV_1 and SV_2. Where SV_1 is the Set of E_n for Which the Total Bit Rate $S(E_n, K_n)$ Equals or Exceeds the Target Bit Rate ρ. The Set SV_2 Contains the Remaining Elements of $\{E_n\}$.
470
480
480(b)
Set SV_1 Empty
YES
490
480(a)
NO
Step 9: For Each Selection Vector E_n in Set SV_1, Iteratively Reduce the K_n Component Associated with the Minimum Margin Band, Stopping Just before Making $S(E_n) < \rho$. Repeat for Second Lowest Margin, Then Third Lowest, etc. Update M_n and $S(E_n, K_n)$ Following Each Reduction in a Component of K_n.
Step 10: Define Set X as Those Elements E_n of Set SV_1 Whose Minimum Margin Function m_n All Have the Greatest Value. Select From Set X the Element E_{n0} whose Maximum Applied Constellation Component is the Least, or Whose Next Minimum Margin Component is Greatest.
492
Step 11: Define Set Y as Those Elements E_n of Set SV_2 Whose Total Bit Rate Function $S(E_n, K_n)$ Has the Greatest Value. Select From Set Y The Element E_{n0} Whose Maximum Applied Constellation Component is the Least, or Whose Minimum Margin Component is Greatest.
494
C

FIG. 8



Start
Set $r = 1$. Where r Refers to SNR Margin Component Inverse Rank So That r= 1 Refers to the Lowest SNR Margin Component and r= B Refers to the Highest SNR Margin Component.
500
Set i_r = The Component Number of M_n With the r'th Smallest Value. For Example, if the 3rd Component of M_n is the Minimum Component and the 7th Component is the Maximum, then $i_1 = 3$ and $i_B = 7$.
$Set K_n^{ir} = K_n^{ir} - 1 (decrement K_n^{ir})$ Re-compute $S(E_n)$, M_n
510
YES
$S(E_n) \geq \rho$
520
NO
$Set K_n^{ir} = K_n^{ir} + 1 (increment K_n^{ir})$
r=r+1
(Increment r)
NO
r=B
530
YES
Re-compute $S(E_n)$, M_n, m_n
Finish

FIG. 9

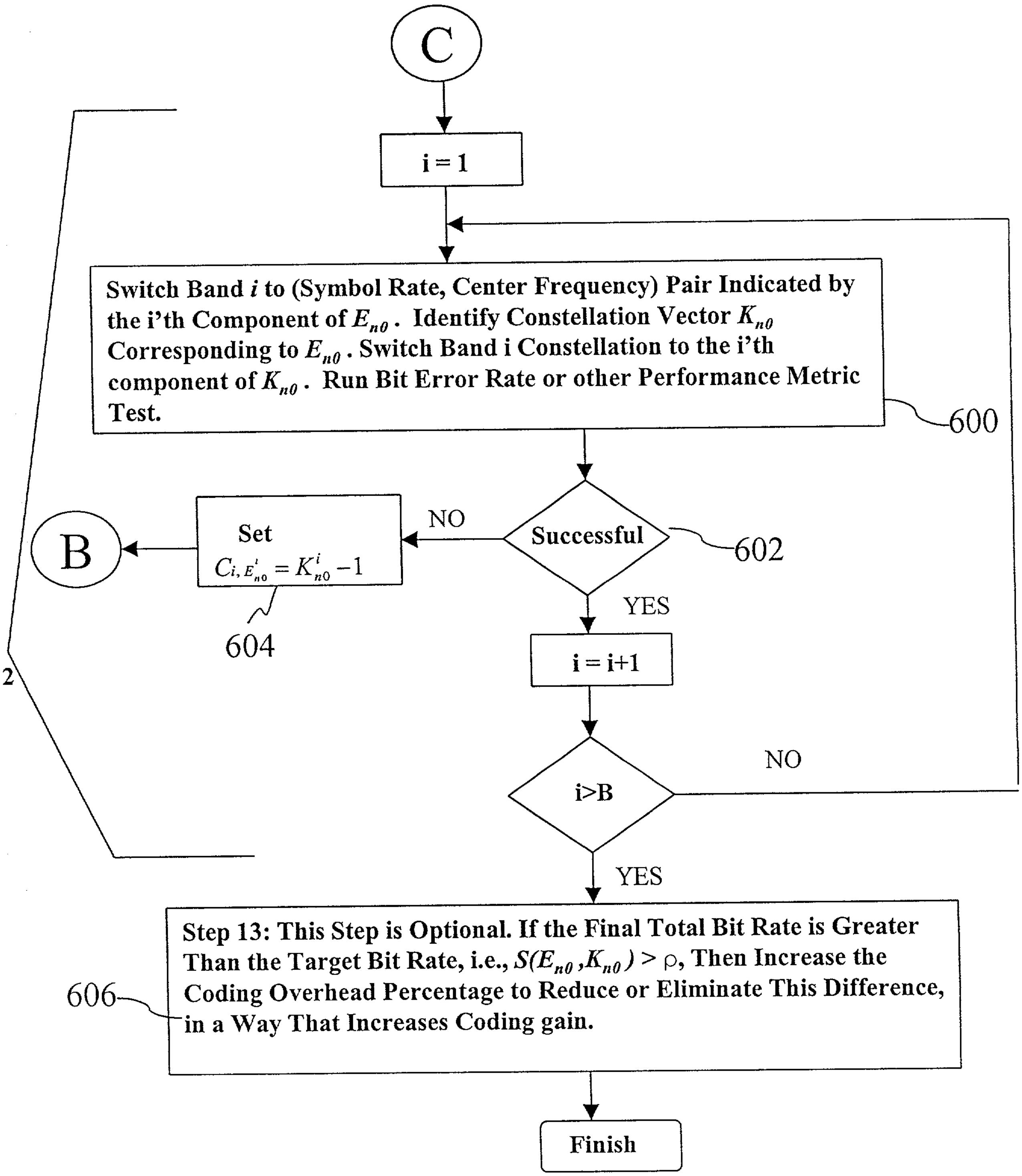

C
i = 1
Switch Band i to (Symbol Rate, Center Frequency) Pair Indicated by the i'th Component of E_{n0}. Identify Constellation Vector K_{n0} Corresponding to E_{n0}. Switch Band i Constellation to the i'th component of K_{n0}. Run Bit Error Rate or other Performance Metric Test.
600
Successful
602
NO
Set $C_{i,E^{i}_{n0}} = K^{i}_{n0} - 1$
604
B
YES
i = i+1
i>B
NO
YES
Step 12
Step 13: This Step is Optional. If the Final Total Bit Rate is Greater Than the Target Bit Rate, i.e., $S(E_{n0}, K_{n0}) > \rho$, Then Increase the Coding Overhead Percentage to Reduce or Eliminate This Difference, in a Way That Increases Coding gain.
606
Finish

FIG. 10

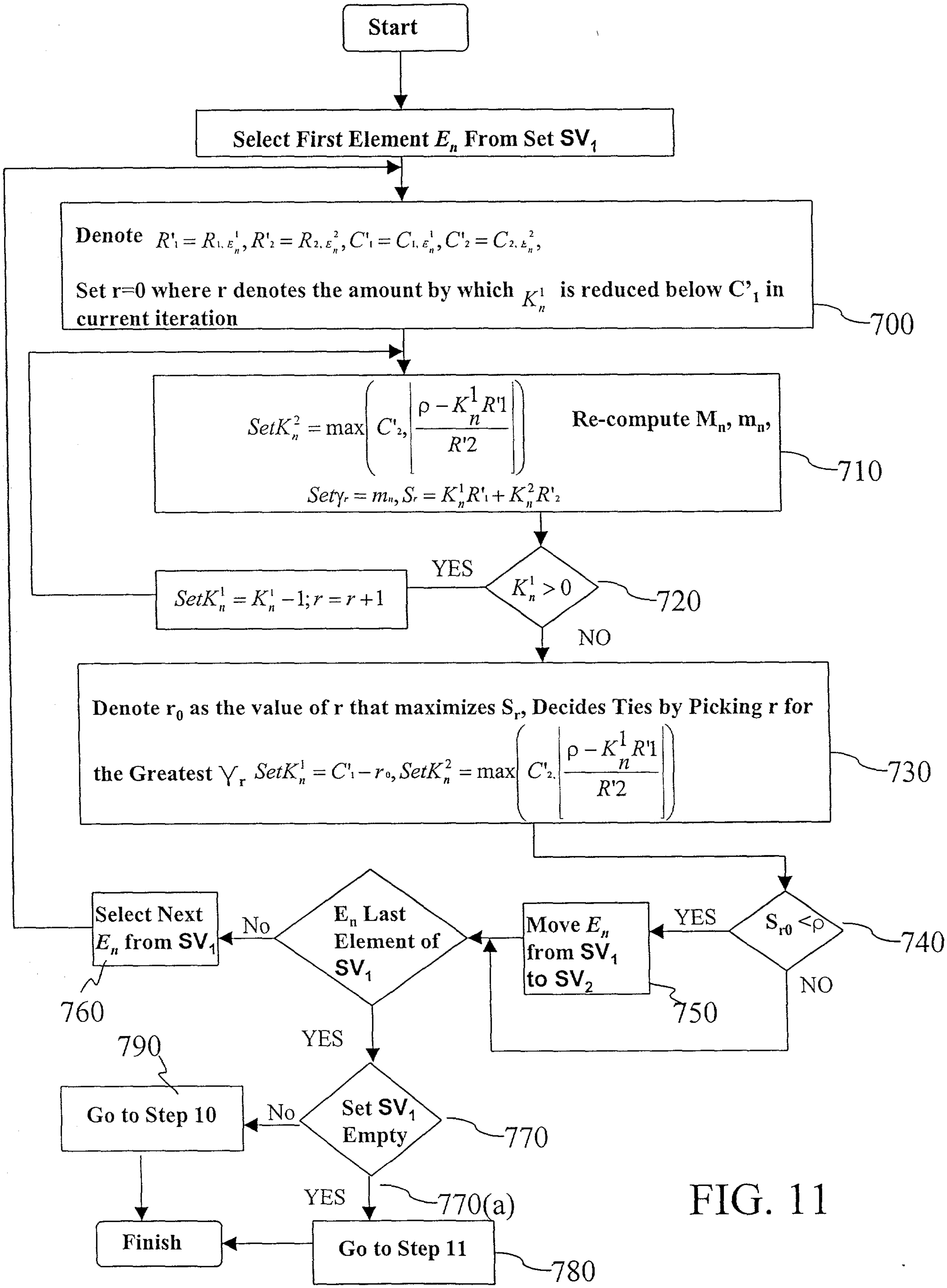

Start
Select First Element E_n From Set SV_1
Denote $R'_1 = R_{1,E_n^1}, R'_2 = R_{2,E_n^2}, C'_1 = C_{1,E_n^1}, C'_2 = C_{2,E_n^2}$,
Set r=0 where r denotes the amount by which K_n^1 is reduced below C'$_1$ in current iteration
700
$Set K_n^2 = \max\left(C'_2, \left|\frac{\rho - K_n^1 R'1}{R'2}\right|\right)$
Re-compute M_n, m_n,
$Set \gamma_r = m_n, S_r = K_n^1 R'_1 + K_n^2 R'_2$
710
YES
$Set K_n^1 = K_n^1 - 1; r = r+1$
$K_n^1 > 0$
720
NO
Denote r_0 as the value of r that maximizes S_r, Decides Ties by Picking r for the Greatest γ_r $Set K_n^1 = C'_1 - r_0, Set K_n^2 = \max\left(C'_2, \left|\frac{\rho - K_n^1 R'1}{R'2}\right|\right)$
730
Select Next E_n from SV_1
No
E_n Last Element of SV_1
Move E_n from SV_1 to SV_2
YES
$S_{r0} < \rho$
740
NO
760
750
YES
790
Go to Step 10
No
Set SV_1 Empty
770
YES
770(a)
Finish
Go to Step 11
780

FIG. 11